CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

Optimized Vertical Profiles

Improving Efficiency in Daily Operations

Scott Williams

Environmental Working Group

17 May 2010

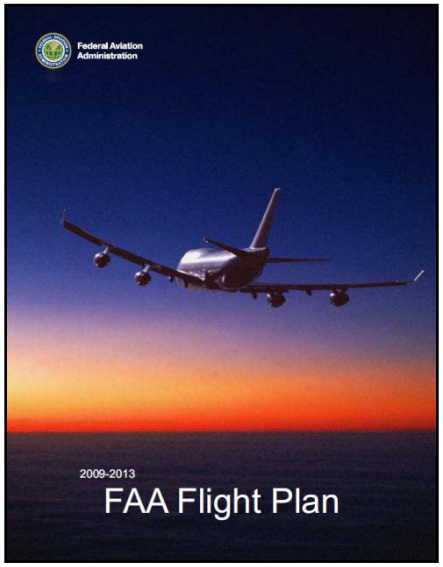
CAASD

MITRE

F062-B10-016

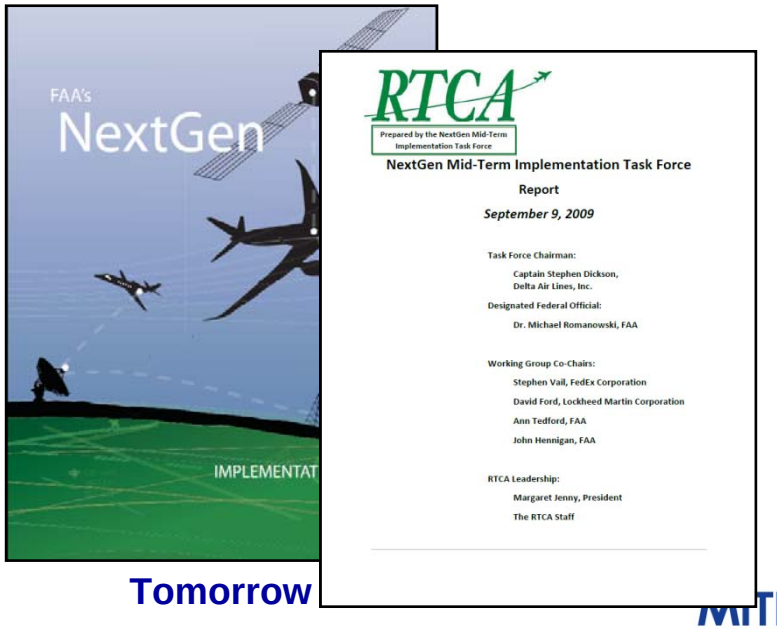
Today to NextGen

- **Today, new RNAV SIDS/STARS principally consist of procedures that closely mirror current vector patterns or their conventional counterpart**
  - **The reasons for this range from airspace complexity to criteria limitations to environmental constraints on large procedural changes**
- **The current National Airspace Procedures Team (NAPT) list has 307 RNAV SIDS/STARS planned between now and the end of CY 2011**
  - **173 of these procedures are "new" designs/implementations**
- **How can we make these and future procedures measurably more efficient and/or environmentally beneficial?**



Today

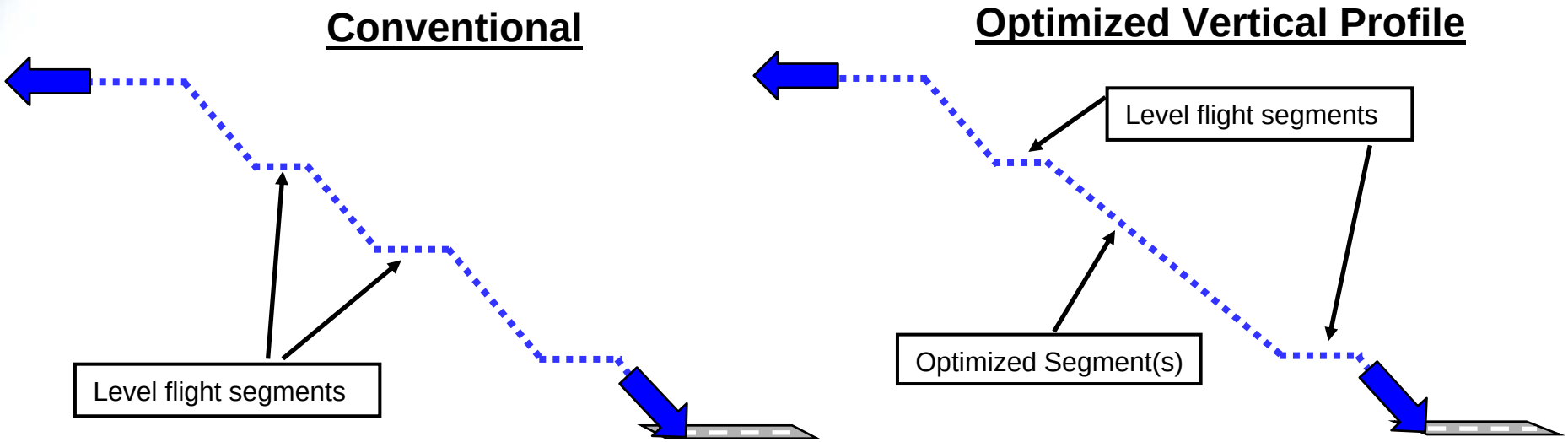
Near Term Transition



Tomorrow

Optimized Vertical Profiles

Arrivals and Departures

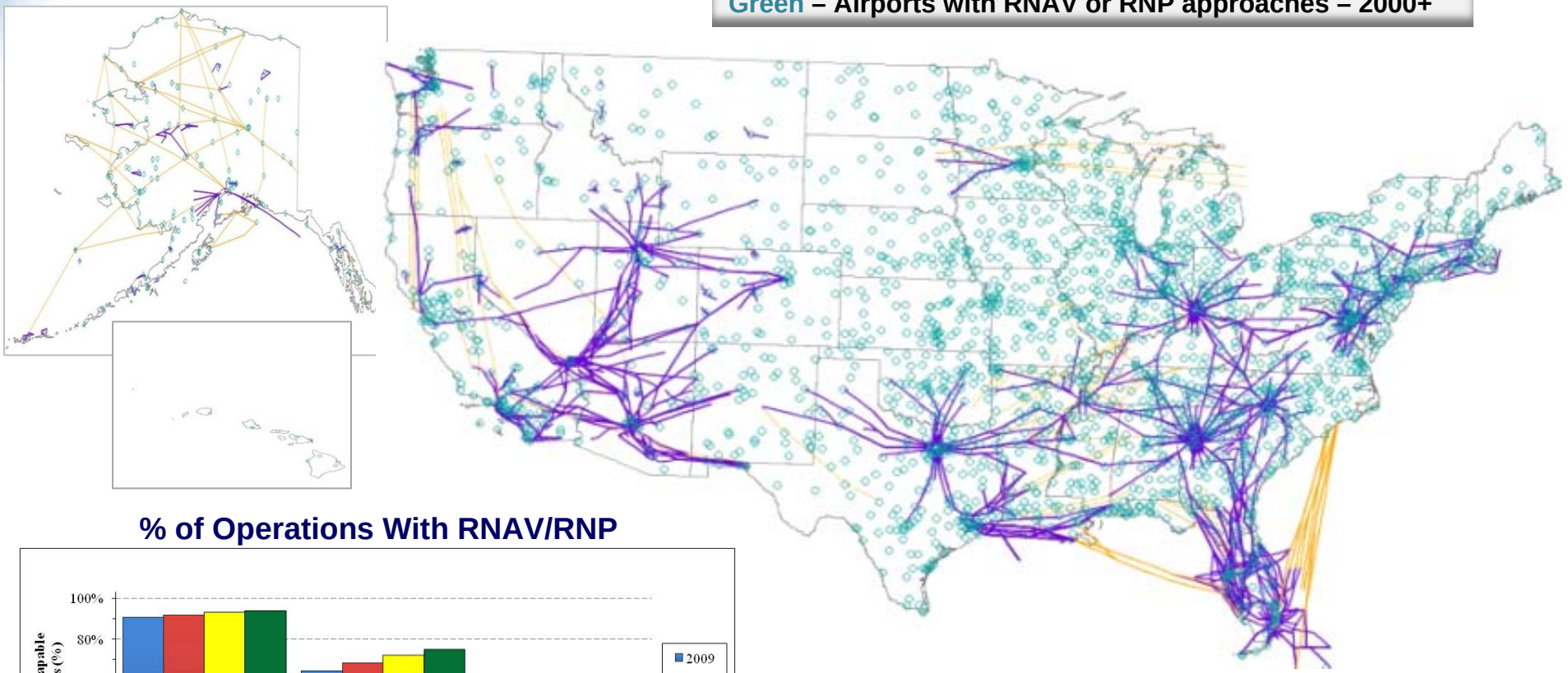


- **Leverages RNAV SID/STAR implementations**
- **Reduce the amount of time spent in level flight on published procedures (i.e., SIDS/STARs) for less fuel/emissions**
  - **Published procedures will principally consist of PBN procedures though not exclusively (i.e., LAX arrivals)**

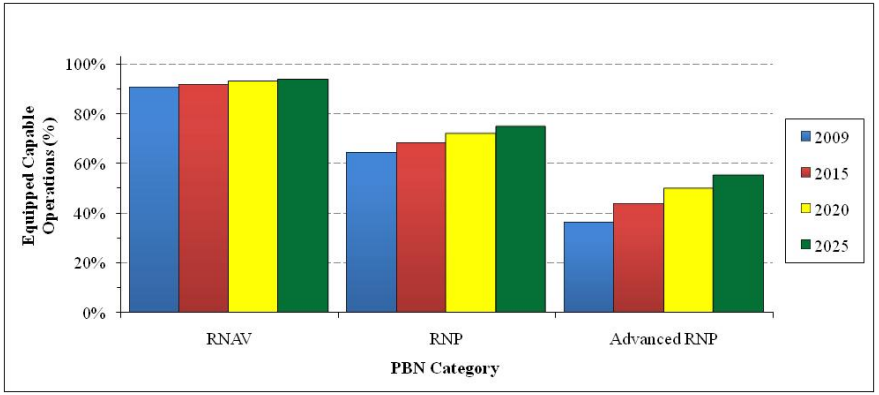
MITRE

NAS RNAV/RNP Implementation

Purple – RNAV SIDs/STAR – 339
Yellow – RNAV En route – 124
Green – Airports with RNAV or RNP approaches – 2000+



% of Operations With RNAV/RNP



RNAV/RNP Implementation in the NAS

MITRE

Optimized Vertical Profiles

Where are we today?

- **There are over 1,600 conventional and RNAV SIDS and STARS in the NAS today**
- **OPDs have been published for every day operations at PHX, SAN, and LAX (RNAV and conventional procedures respectively)**
  - **7 procedures total at these airports**
- **Other OPD implementations or planning include**
  - **Atlanta (ATL)**
  - **Louisville (SDF)**
  - **Charleston (CHS)**
  - **Hawaii (HCF)**
  - **Memphis (MEM)**
  - **Reno (RNO)**
  - **Anchorage (ANC)**
  - **Las Vegas (LAS)**
  - **Denver (DEN)**
- **Can we do more, can we improve results, at a faster pace?**

MITRE

Near Term Transition

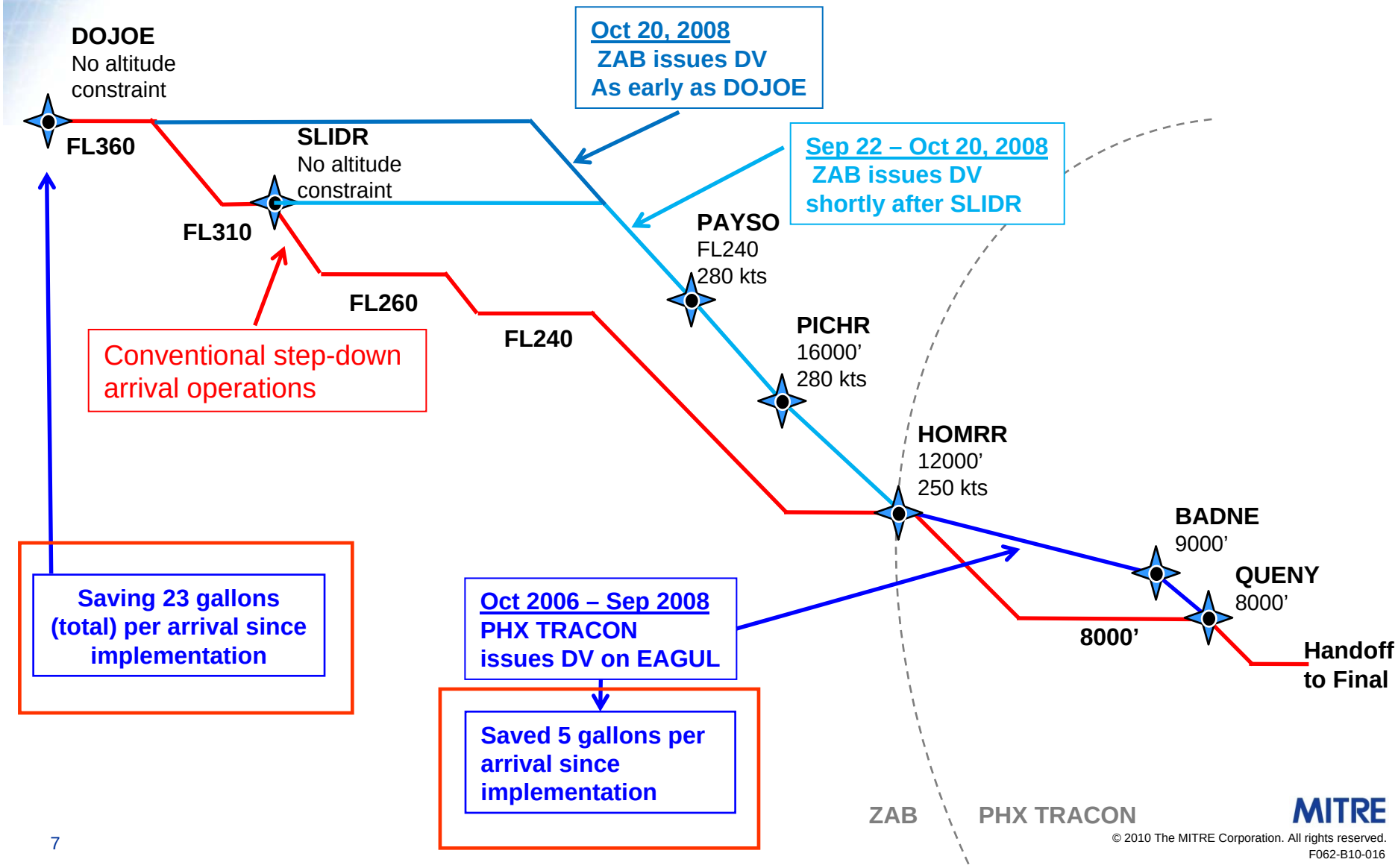
- **FAA Goal:**
  - **Integrated Airspace and Procedure design**
  - **Site-specific modeling and analysis and a commitment from stakeholders is pivotal to success**
    - **Optimized vertical profiles for departures and arrivals**
- **How do we move then from today's designs and implementations to more optimized/beneficial designs?**
  - **Integrated SID/STAR design/implementation**
  - **Focus development resources toward the near term**
  - **Target efficiency/environmental goals on each design/implementation**
- **Are near term benefits achievable?**
  - **Absolutely but it takes additional resources and coordination**
- **What are the potential benefits?**

MITRE

F062-B10-016

Phoenix OPD

EAGUL RNAV STAR Procedure with Descend Via (DV) Ops



MITRE

Fuel & Emission Benefits at PHX

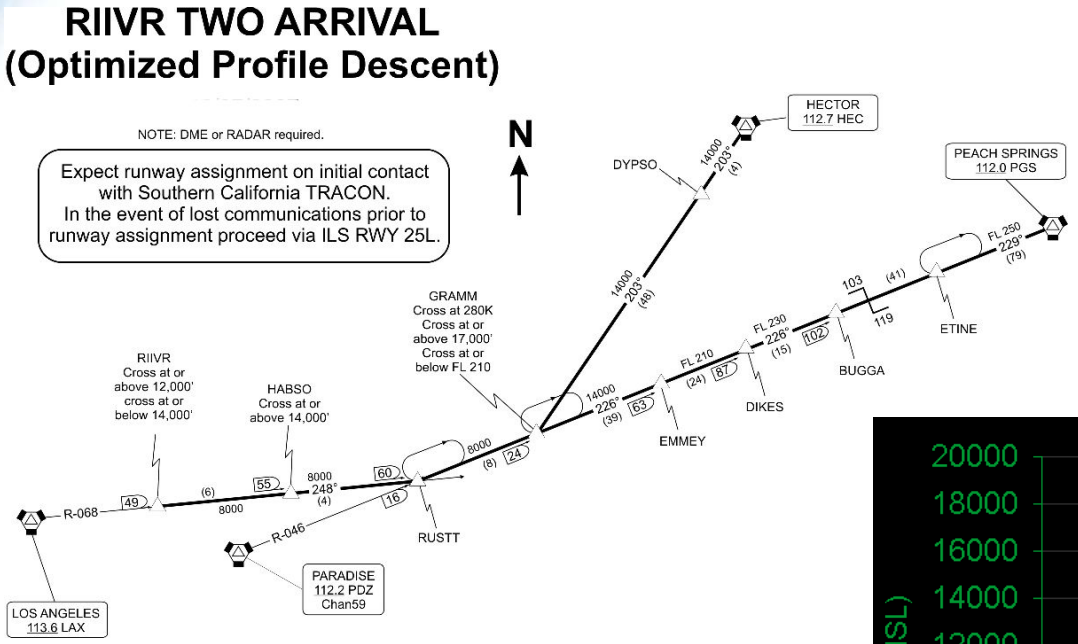
This table shows the reductions in emissions and fuel as a result of descend via implementation from SLIDR and DOJOE

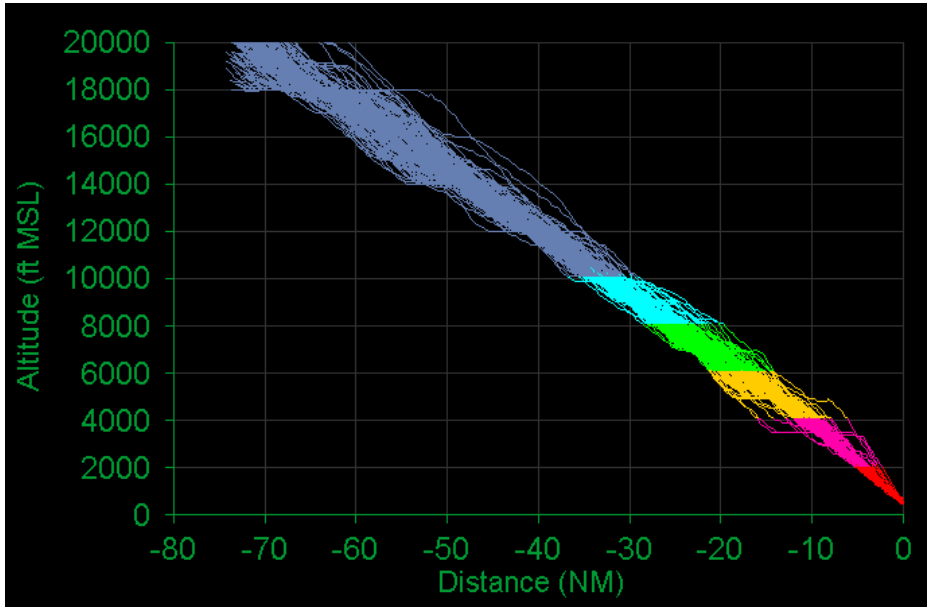
	CO_2 (t)	SO_2 (t)	Fuel (gallons per arrival)	Cost savings (annualized)*
DV from SLIDR				
All Tracks	1831	0.46	4	$0.4M-$0.8M
RNAV	644	0.17	2	$0.1M-$0.3M
DV from DOJOE				
All Tracks	8735	2.18	23	$1.8M-$3.6M
RNAV	7028	1.80	23	$1.5M-$2.9M

*Based on estimated fuel cost of $2-$4 per gallon

MITRE

Los Angeles OPDs





- **Enables 50% of LAX traffic an OPD**
- **96% compliance with the vertical profile**
- **Fuel savings of over 2 million gal annually ($4-6 Million dollars)**
- **Reductions in CO^2 emissions estimated at over 41 million metric tons annually**

MITRE

RNAV OPD Site Selection

- **Conducted a high-level NAS-wide analysis of airports to prioritize OPD implementation sites**
- **Analyzed 4,500+ arrival flows at 158 airports across the NAS**
- **Analysis places statistical weight on the metric categories**
  - **Weights can be adjusted to address implementation priorities**
  - **Example: Using a 45/45/10 percent weighting**

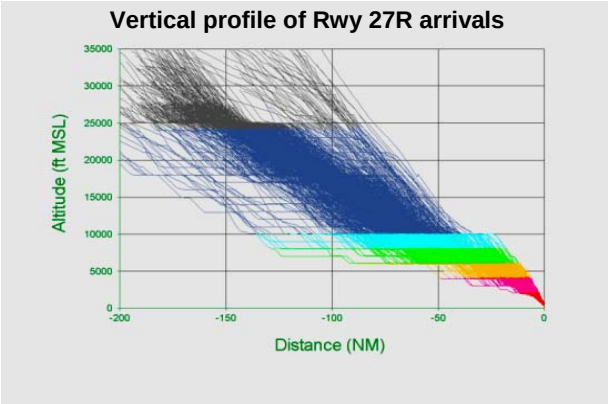
Composite 45/45/10 List	
Rank	Airport
1	STL – St. Louis, MO
2	MHT – Manchester, NH
3	PIT – Pittsburgh, PA
4	CVG – Covington, KY
5	RDU – Raleigh-Durham, NC
6	FLL – Fort Lauderdale, FL
7	PHX – Phoenix, AZ
8	MCO – Orlando, FL
9	SAN – San Diego, CA
10	SLC – Salt Lake City, UT

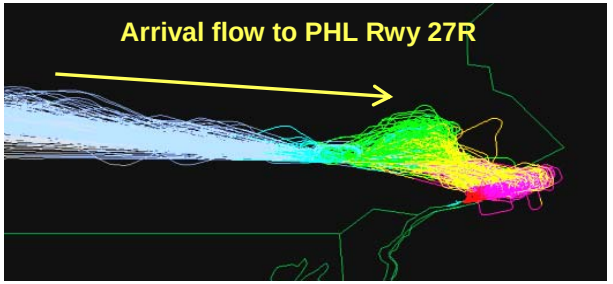
PHL

Analysis of one arrival flow at PHL

Average daily arrival count at airport	Number of centers	Number of level-offs	Percent vectoring
660 arrivals	2.6	5	26%

Average daily arrival count along flow	Percent Part121 Ops	Percent Jet Ops	Average time in level flight per aircraft
142 arrivals	76%	84%	585 s





MITRE

Benefits Analysis

- **Operational data from these 10 airports combined with benefits estimates yield significant monetary and carbon savings**

Composite 45/45/10 List	
Rank	Airport
1	STL – St. Louis, MO
2	MHT – Manchester, NH
3	PIT – Pittsburgh, PA
4	CVG – Covington, KY
5	RDU – Raleigh-Durham, NC
6	FLL – Fort Lauderdale, FL
7	PHX – Phoenix, AZ
8	MCO – Orlando, FL
9	SAN – San Diego, CA
10	SLC – Salt Lake City, UT

	5 gal per flight	15 gal per flight
Savings (Gal/day)	7324	21973
$3 / Gal ($/day)	$21,973	$65,919
Annual Savings	$8,020,093	$24,060,279
CO2 Reduction (tons/year)	26734	80201
Cars off road (cars / year)	4456	13367
Cumulative savings: 2010-2035	$200,502,321	$601,506,964

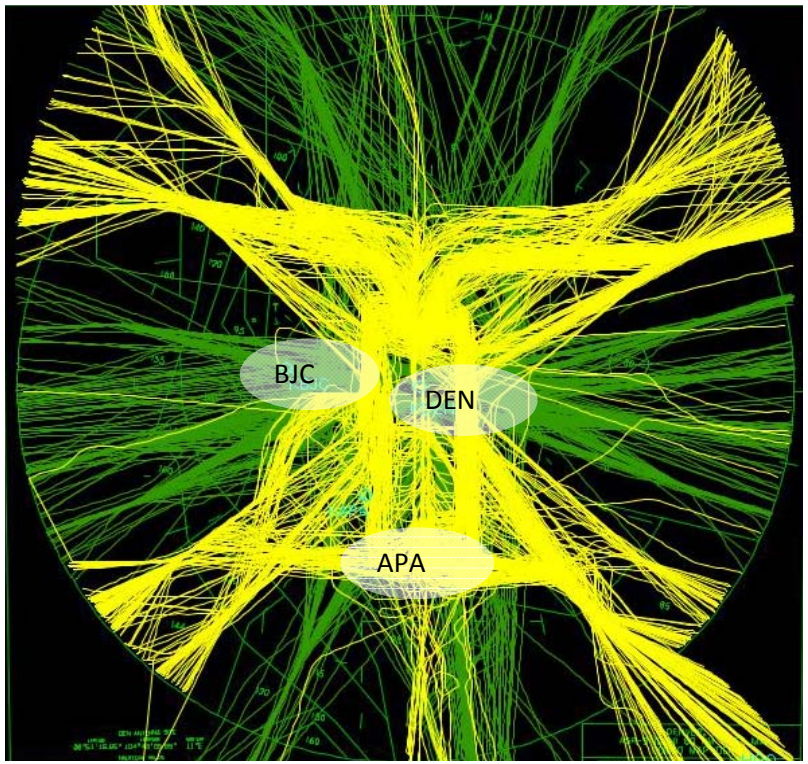
- **How do we leverage modeling and analysis to optimize integrated airspace and procedures?**
  - **It requires ATC facility(s) and operator consensus and it begins with the kickoff meeting...**

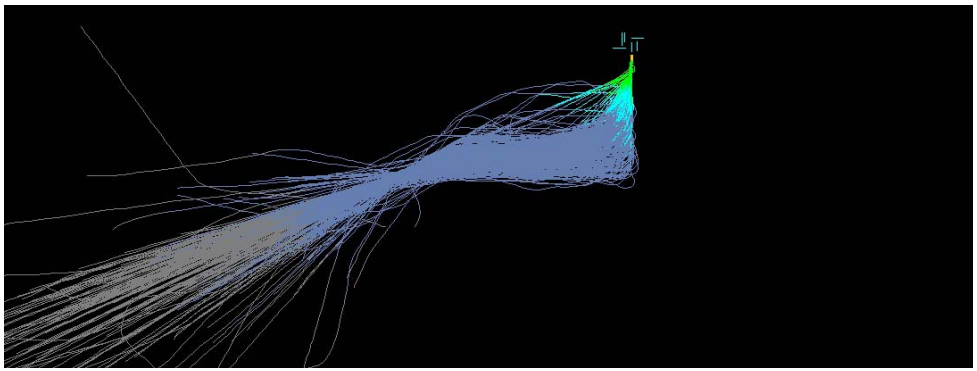
MITRE

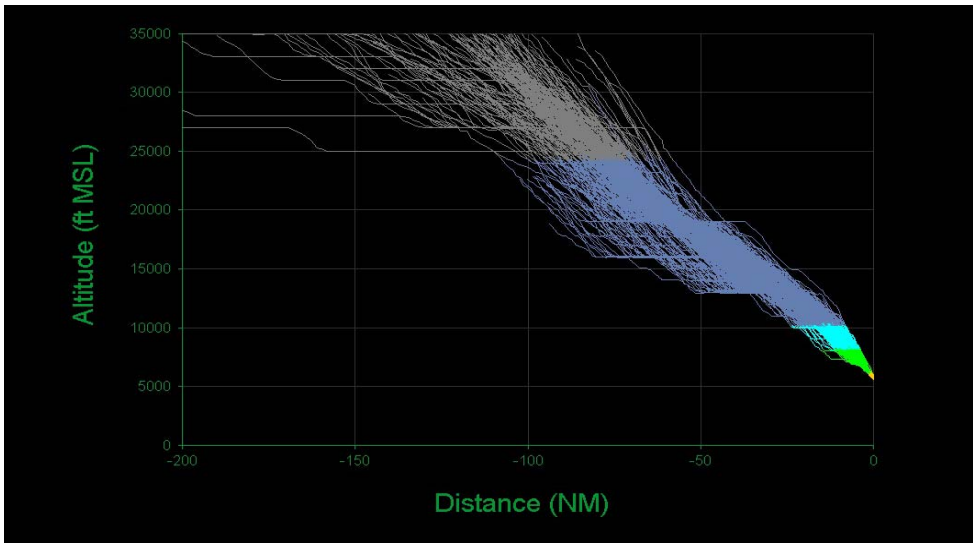
Kickoff Meeting

Start with Operational Homework

- **Assess the operating environment to discover opportunities for efficiency gains**







MITRE

F062-B10-016

Kickoff Meeting

Where are Efficiency Opportunities?

- **Analyze departure/arrival flows to target opportunities for modified procedures**

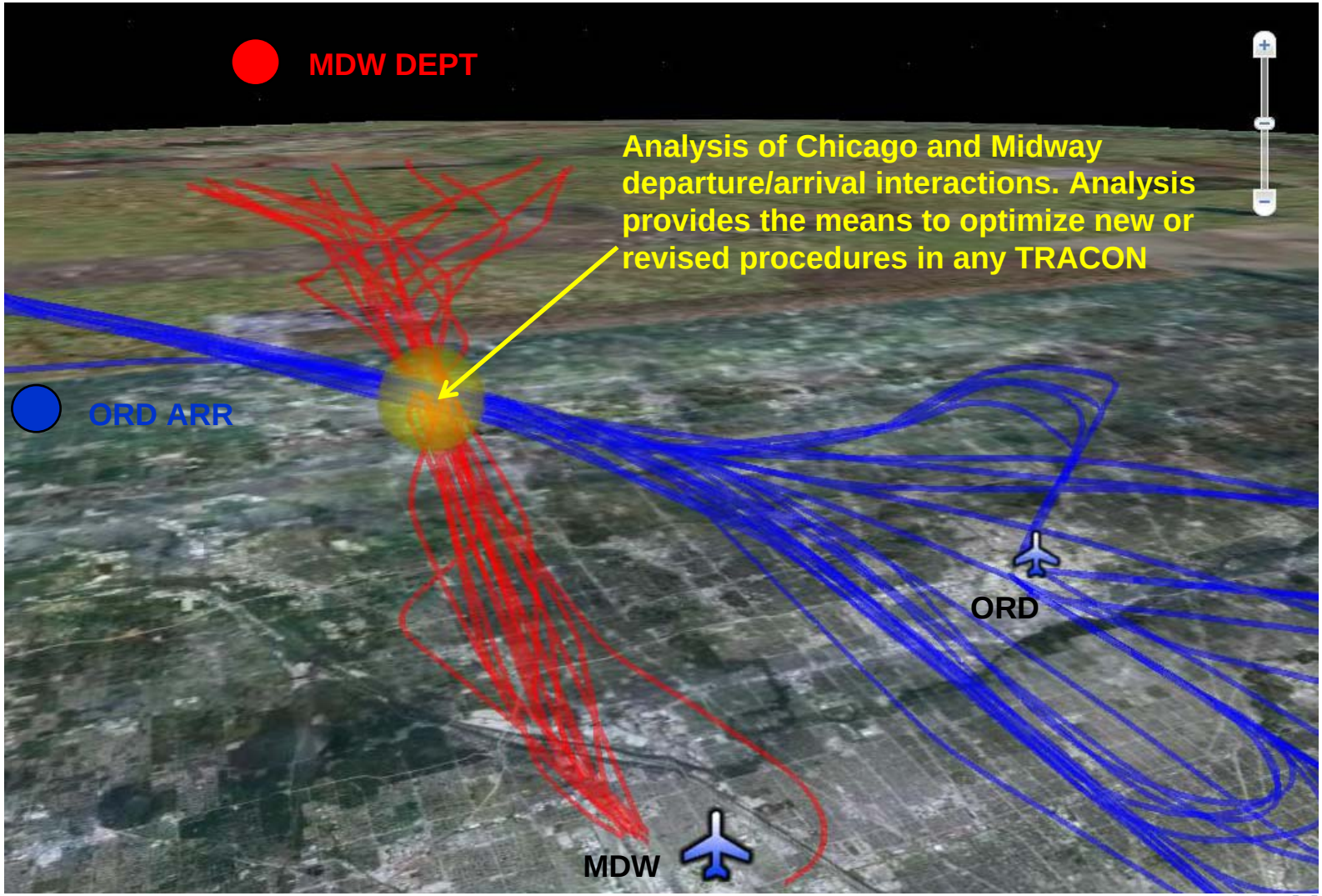
Average daily arrival count along flow	Percent Part121 Ops at the airport	Percent Jet Ops at the airport	Time in level flight per aircraft along flow	Number of Level Offs	Number of Facilities Involved
48 arrivals	87%	81%	244 s	5	1

Selected Altitudes	Time in Level Flight (sec)	Gal/min burn rate	Gal/day burned	Cost/day ($)	CO2 emitted (tons/day)
9000	26	9.9	205	600	2
11000	42	9.9	335	1000	3
13000	94	9.9	741	2200	7
14000	12	9.9	99	300	1
19000	45	10.0	356	1100	3

MITRE

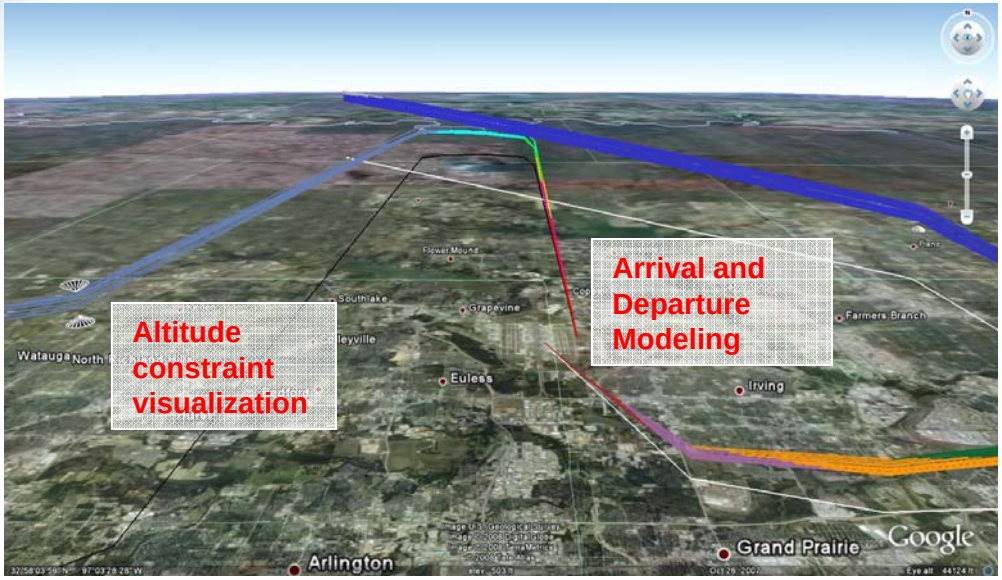
Kickoff Meeting

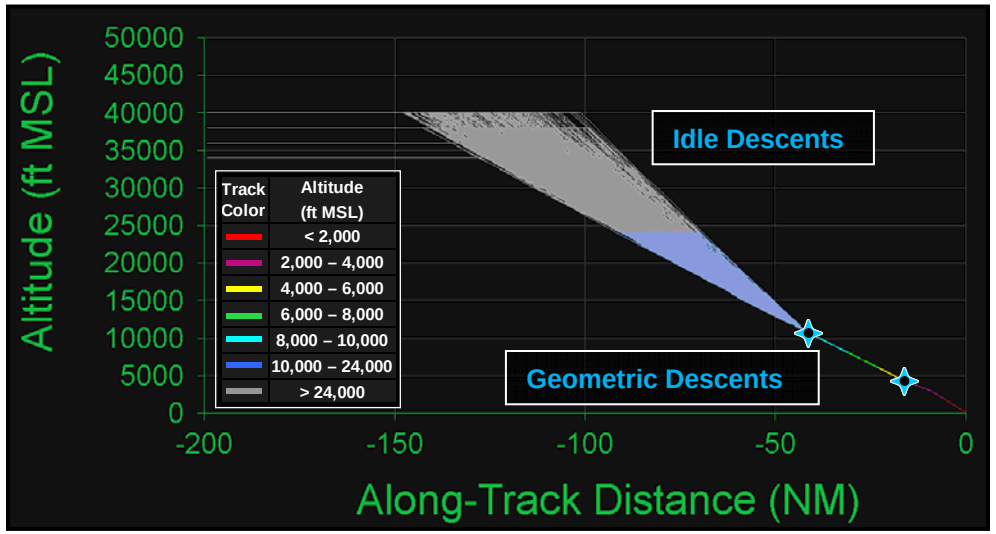
Where are Efficiency Opportunities?



Kickoff Meeting

Modeling, Analysis and Design Options





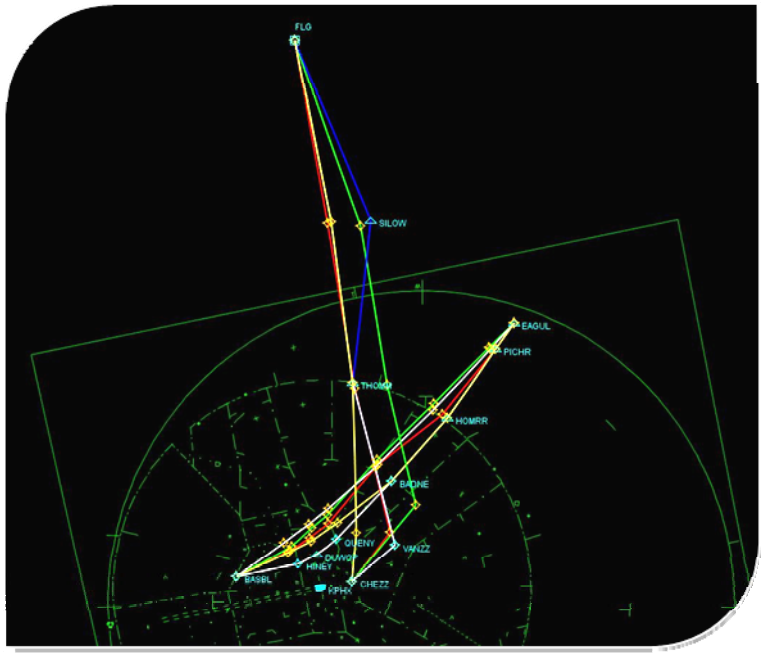
- **FAA tasked MITRE to develop a trajectory model for procedure design support**
- **Enables fast time fuel burn, emissions, and track metrics analysis**
- **Models FMS VNAV path construction**
- **Addresses operational variability**
  - Fleet Mix
  - Wind
  - Cost Index
  - Speed restrictions
- **On the spot simulation to test design options and variability**

MITRE

Real Time Design Collaboration

Modeling, Analysis and Design Options

- **Trajectory modeling provides an understanding of how an aircraft will fly post-implementation**
- **This allows for an analysis of the magnitude of benefit a procedure may provide**
- **This also allows for modeling the benefit delta between multiple procedure designs**



Fuel Burn (kg/ flight)	STAR_R0	STAR_R1	STAR_R2	STAR_C1	STAR_C2
SID_D0	1227.4	1224.1	1226.0	1223.9	1223.3
SID_D1	1213.4	1210.1	1211.9	1209.9	1209.3
SID_D2	1181.5	1178.2	1180.1	1178.0	1177.4
SID_C1	1202.9	1199.7	1201.5	1199.5	1198.8
SID_C2	1224.2	1220.9	1222.8	1220.7	1220.1

MITRE

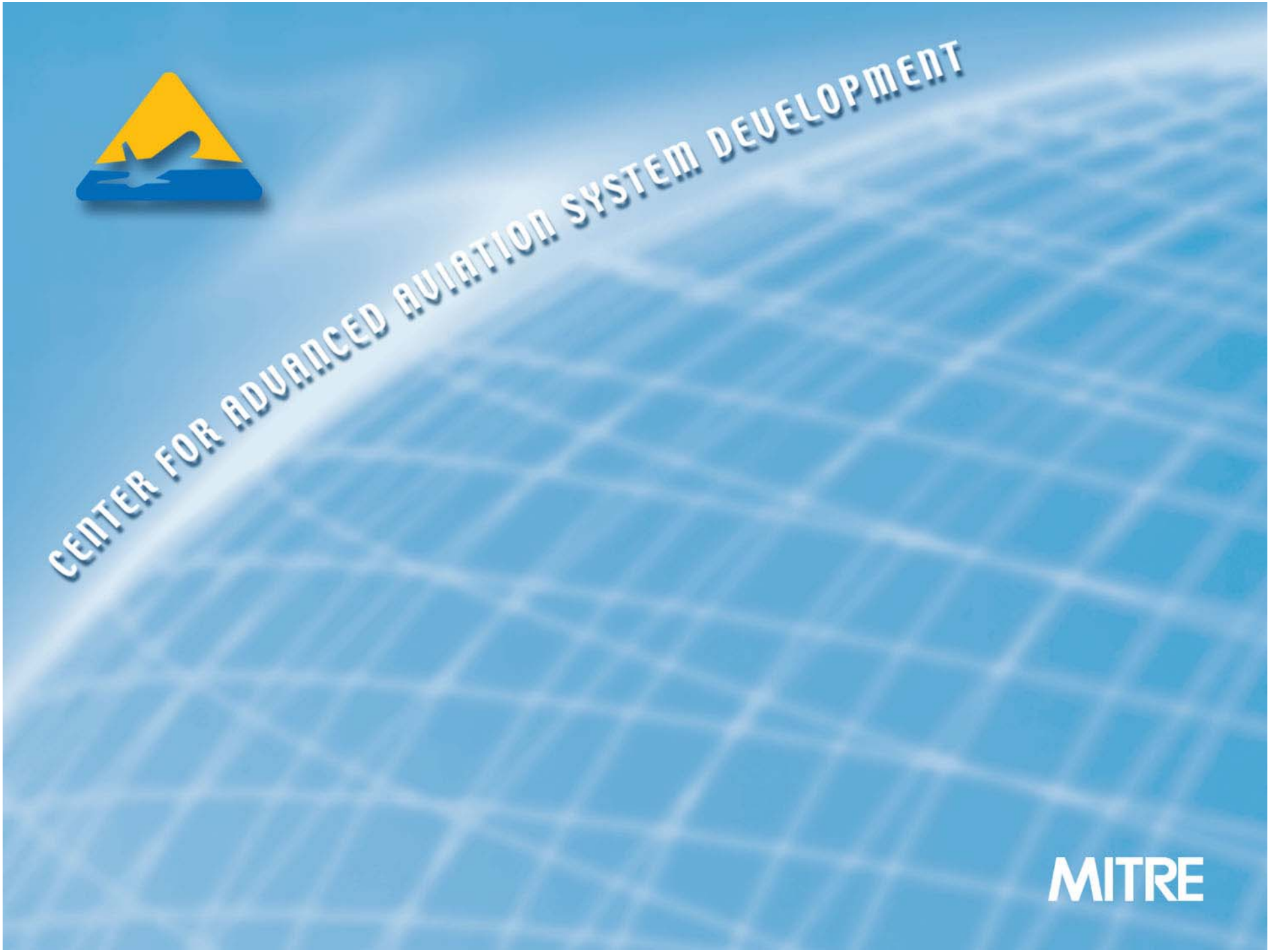
Summary

- **Optimized Vertical Profiles can produce significant cost and environmental savings**
  - **One part of the FAA strategy for Integration of Airspace and Procedures that will maximize benefits to the widest net of stakeholders**
  - **FAA is working locations today: ATL, MIA, CHS, BHM, SDF, LAX, STL, PHL, ABQ**
- **Begin the process and set goals at kickoff and measure progress against those goals**
- **Implementation challenges**
  - **Environmental requirements**
  - **Airspace complexity**
  - **Mixed equipage**
  - **Facility readiness and site specific airspace design/re-design**
  - **Automation**

BUT

- **Near-term benefits will result from taking design/implementation to the next step and addressing those challenges**

MITRE


CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT
MITRE